Flight Test Results of VDL-3, 1090ES, and UAT Datalinks for Weather Information Communications

I-CNS Briefing

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Outline

added objectives.

Commercial Transport
- 1090ES
- VDL-3

General Aviation
- UAT

Commercial Transport

added objectives.

Transmission of on-board sensed turbulence information to ground users and between aircraft.

1090ES for Air-to-Air
VDL-3 Air-to-Ground

Broadcast graphical weather products to the pilot.

VDL-3

Air-to-Air

added objectives.

1090ES

Turbulence Alert Message

added objectives.

- The turbulence alert message consisted of the following parameters:

    1. Time
    2. Latitude
    3. Longitude
    4. Altitude
    5. Processed Normal Load
    6. Processed Aircraft Constant

- Standard ADS-B messages already contain the first four parameters, it is only necessary to broadcast two additional parameters. These two additional parameters are each eight bits long, totaling an additional 16 bits to be transmitted. The additional parameters will be formatted as a payload to a standard ADS-B message, in compliance with DO–260
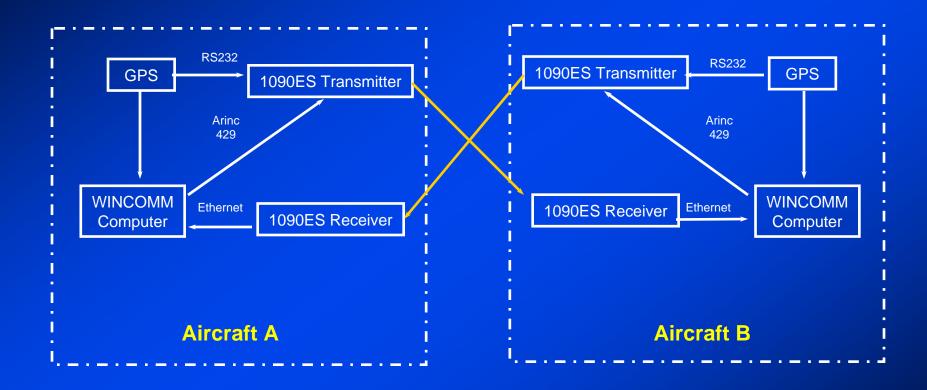
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Turbulence Alert Message

•In compliance with DO-260, with a downlink format (DF) of 17 (standard for ADS-B messages over 1090ES).

• Uses the test type code (23), and BDS codes 4 & 5 (already designated in ICAO Annex 10, Volume II, as Meteorological Hazard Report).

• The messages are sent as encountered turbulence exceeds one of three thresholds, but is never transmitted at a rate greater then once per 60 seconds. (For testing purposes a message is sent every 60 seconds.)

1	MSB	1
2		0
3	FORMAT TYPE CODE = 23 (TEST)	1
4		1
5	LSB	1
6		1
7	SUBTYPE CODE = 6	1
8		0
9	MSB	
10		
11	Load-Based Parameter	
12		
13	LSB	
...	MSB	
...	Aircraft Constant	
20	LSB	
21	Pad with Zeros	
... 324		

1090ES Data Flow

Aircraft A

GPS
RS232
1090ES Transmitter

Arinc 429

WINCOMM Computer
Ethernet
1090ES Receiver

Aircraft B

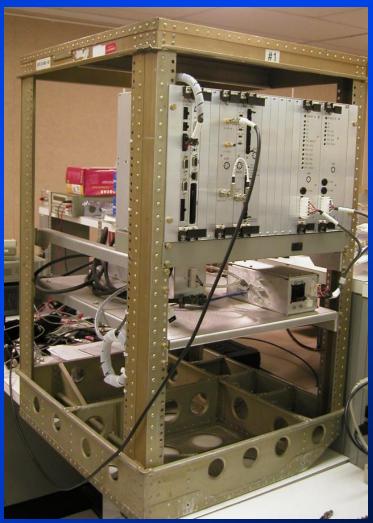1090ES Transmitter
RS232
GPS

Arinc 429

1090ES Receiver
Ethernet
WINCOMM Computer

1090ES Equipment
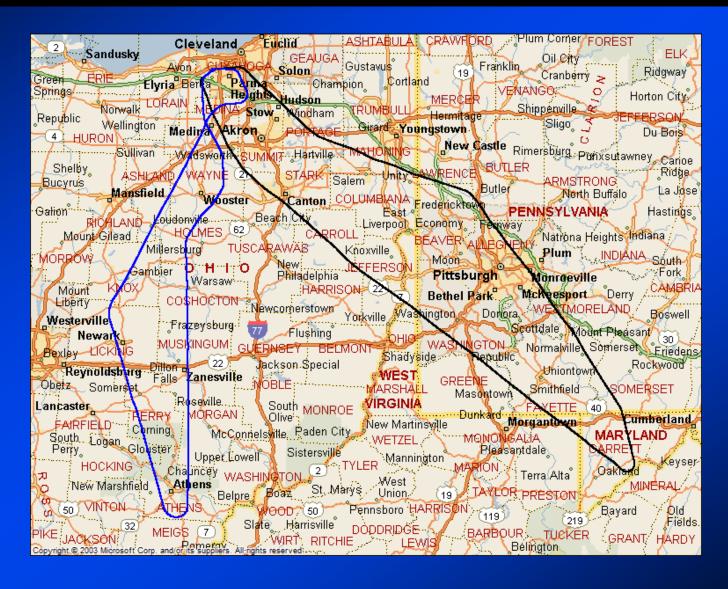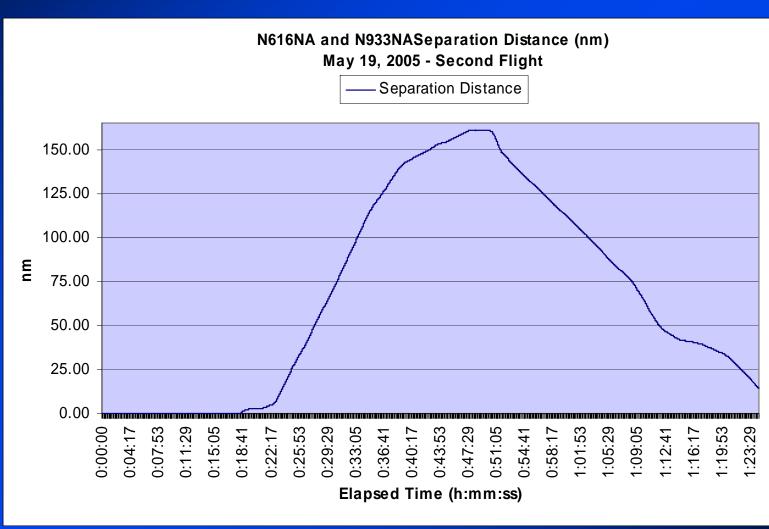
1090ES Flight #3

1090ES Flight #3

N616NA and N933NASeparation Distance (nm)
May 19, 2005 - Second Flight

Separation Distance

1090ES Message Reception

616 to 933
msg number vs. separation distance (nm)

Legend: ▲ 17-May, ■ 19-May_1, □ 19-May_2, △ 15-Jun

933 to 616
msg number vs. separation distance (nm)
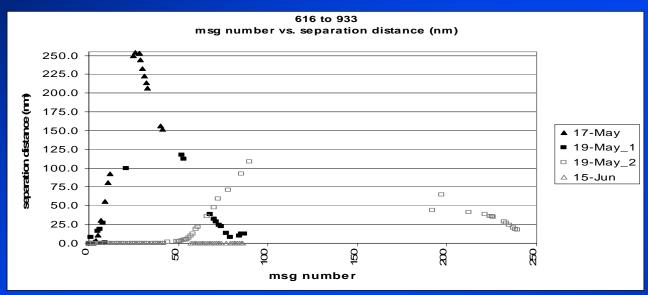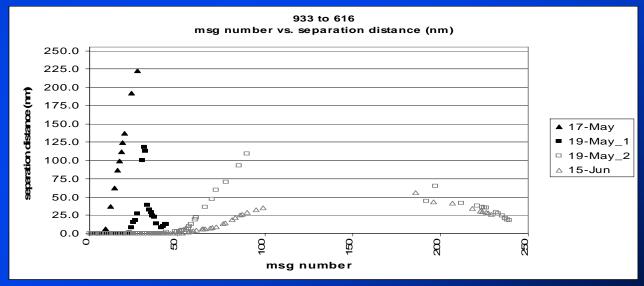
Legend: ▲ 17-May, ■ 19-May_1, □ 19-May_2, △ 15-Jun

1090ES Message Reception 3nm-100nm

Message Rate

60sec

30sec

20sec

Date	Direction	Sent	Received	% Received
May 17	616 to 933	9	6	66.7%
May 17	933 to 616	11	5	44.5%
May 19 – 1	616 to 933	54	15	27.8%
May 19 – 1	933 to 616	53	16	30.2%
May 19 – 2	616 to 933	98	27	27.6%
May 19 – 2	933 to 616	105	28	26.7%
June 15	616 to 933	0	0	0.0%
June 15	933 to 616	171	26	15.2%
TOTAL		501	123	24.6% (average)

Bi-Directional Air-Ground link

added objectives.

VDL - 3

VDL Mode 3 Messages

- Reliable Air-ground turbulence messages

- Reliable Air-ground message for requesting additional graphical weather products

- Broadcast Ground-Air FIS-B weather products

Air-Ground Turbulence Message

added objectives.

- The turbulence message consisted of the following parameters:
  1. Time
  2. Latitude
  3. Longitude
  4. Altitude
  5. Aircraft Weight
  6. Airspeed
  7. Mach Number
  8. Processed Normal Load
  9. Processed Aircraft Constant

- Additional parameters are required beyond those in the turbulence alert message, to allow ground processing of the downlinked messages to be assimilated into weather prediction models and a future national turbulence weather product.

Air-Ground Request Message

added objectives.

• In order to allow pilots to request graphical weather products which may not be part of the standard weather product set, a request message will be transmitted to schedule the uplink of the desired product. This requested product will be transmitted as the channel is available.
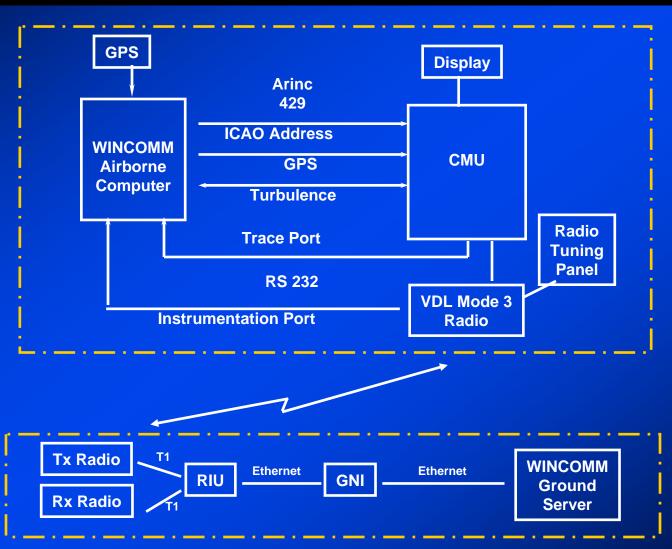
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Ground-Air Weather Products

added objectives.

• For the purposes of the WINCOMM project, the broadcast FIS-B messages consist of the adjacent weather products. These products conform to DO-267 (FIS-B MASPS).

• In addition to the standard products, the pilot requested messages will be transmitted as requested and as the channel is available

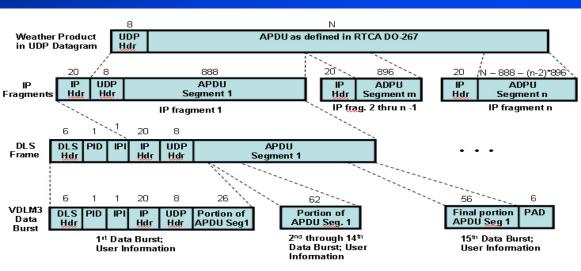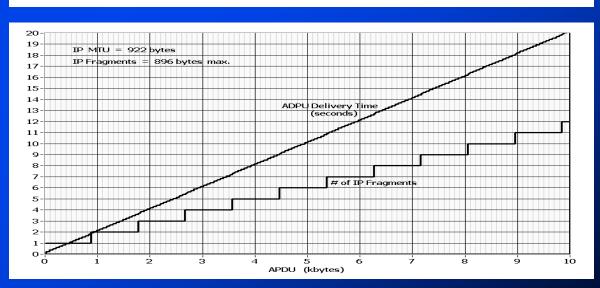| Standard Products	Size (Bytes)
METARs, SPECIs	4,293
SIGMETs, Convective SIGMETs,	
AIRMETs, Severe Weather Forecast Alerts	2,544
TAFs	2,977
PIREPs	2,005
Graphical NexRad	899
Graphical Tops/Movement	1,527
Graphical Weather Depiction	2,220
Requested Products	Size (Bytes)
Graphical Winds/Temps, FL24	2,177
Graphical Winds/Temps, FL30	2,238
Graphical Winds/Temps, FL34	2,311
Graphical Turbulence, FL05	923
Graphical Turbulence, FL24	1,074
Graphical Turbulence, FL30	1,256
Graphical Turbulence, FL34	983
Graphical Icing, FL24	1,021
Graphical Icing, FL30	723
Graphical NexRad, Region: Northwest	401
Graphical NexRad, Region: Northcentral	508
Graphical NexRad, Region: Northeast	1,495
Graphical NexRad, Region: Southcentral	526
Graphical NexRad, Region: Southeast	592

VDL Mode 3 Data Flow

VDL Mode 3

490 bytes per second (3.92 kbps)

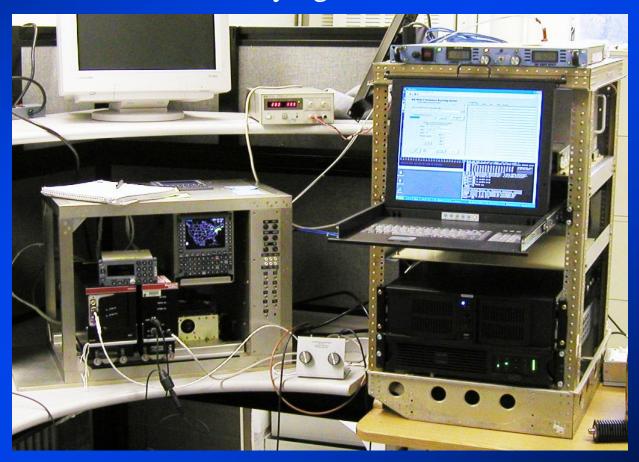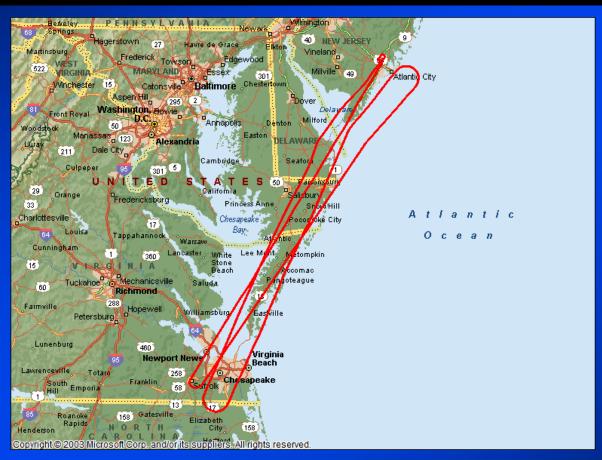# VDL Mode 3 Lab Testing

• Lab testing was conducted at both NASA GRC and at the FAA Technical Center. These tests were conducted in both cabled and RF environments, under varying attenuation schemes.
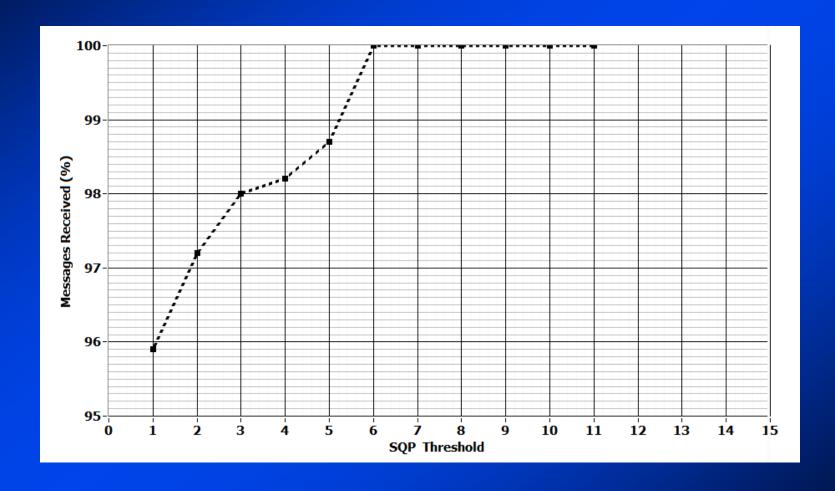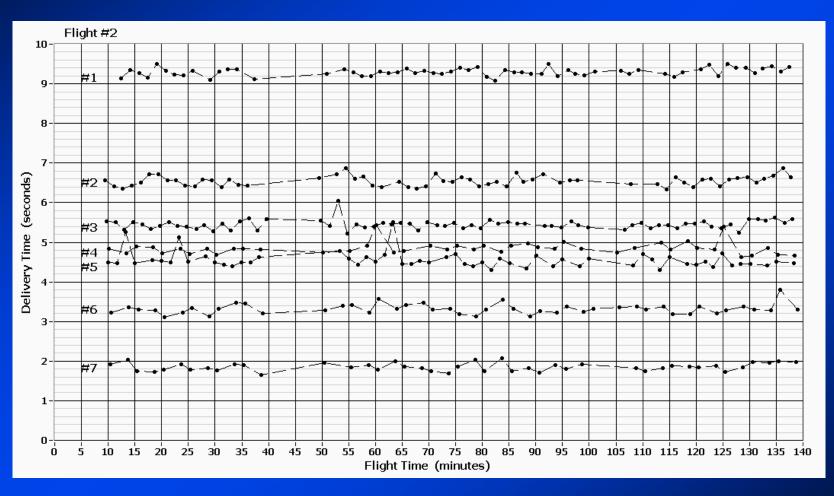
VDL Mode 3 Flight Testing

Five flights (11hrs total) were conducted between April 10-13, 2005, using the FAA Technical Center VDL-3 ground station.
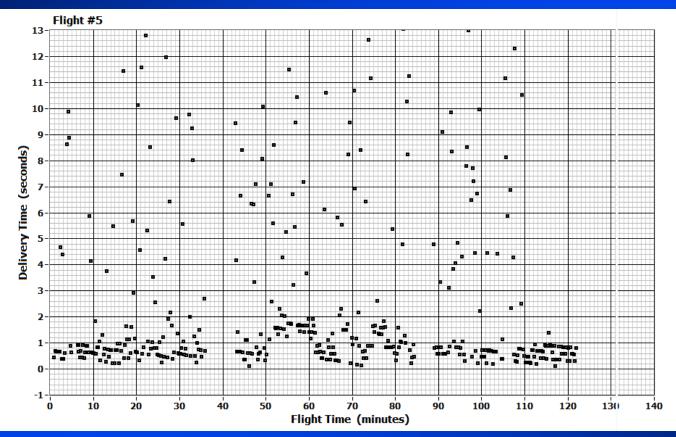
Standard Weather Product Reception

Standard Weather Product Reception

Flight #2

WTP	#1	#2	#3	#4	#5	#6	#7
Bytes	4,293	2,977	2,544	2,220	2,005	1,527	889
Desc.	METAR	Term. Wx	SIGMETS	Wx CONUS	PIREPS	NEXRAD	NEXRAD

Turbulence Message Reception

Flight #5
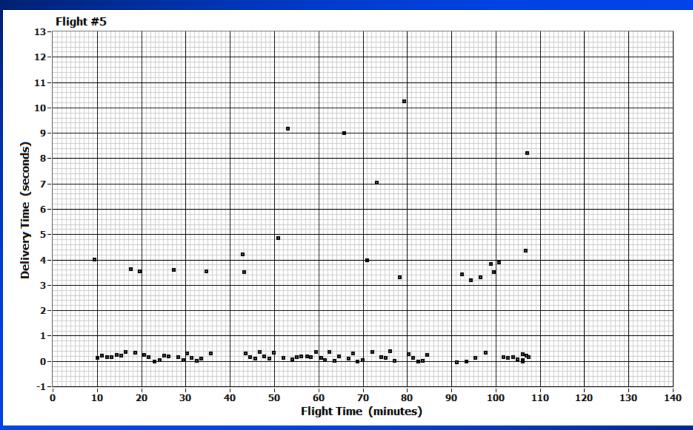
	Flt. #2	Flt. #3	Flt. #4	Flt. #5
TTMs Sent	136	122	217	444
TTMs Rec'd.	136	122	217	444
TTMs Lost	0	0	0	0
Retransmissions:				
at the TCP layer	5	6	20	34
at the DLS layer	55	32	49	93

Request Message Reception

Flight #5 — scatter plot of Delivery Time (seconds) vs Flight Time (minutes)

	Flt. #2	Flt. #3	Flt. #4	Flt. #5
REQs Sent	16	43	43	102
REQs Rec'd.	16	43	43	102
REQs Lost	0	0	0	0
Retransmissions:				
at TCP layer	5	11	6	6
at DLS layer	4	20	8	30

Standard Weather Products
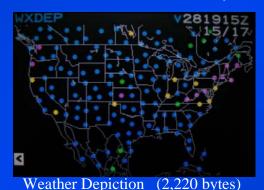
METAR, SPECI   (4,293 bytes)

PIREPS   (2,005 bytes)

Terminal Weather   (2,977 bytes)

SIGMETS, AIRMETS   (2,544 bytes)

NEXRAD, CONUS   (889 bytes)

NEXRAD, w/tops   (1,527 bytes)

Weather Depiction   (2,220 bytes)

Requested Weather Products

Winds/Temps, FL24, 00Z (2,177 bytes)   Winds/Temps, FL30, 00Z (2,238 bytes)   Winds/Temps, FL34, 00Z (2,311 bytes)

Turbulence, FL05, 00Z   (923 bytes)   Turbulence, FL24, 00Z (1,074 bytes)   Turbulence, FL30, 00Z (1,256 bytes)

Turbulence, FL34, 00Z   (983 bytes)   Icing, FL24, 00Z   (1,021 bytes)   Icing, FL 30, 00Z   (723 bytes)

Requested Weather Products

NEXRAD, Northwest (401 bytes)

NEXRAD, Northcentral (508 bytes)

NEXRAD, Northeast   (1,495 bytes)

NEXRAD, Southcentral (526 bytes)

NEXRAD, Southeast   (592 bytes)

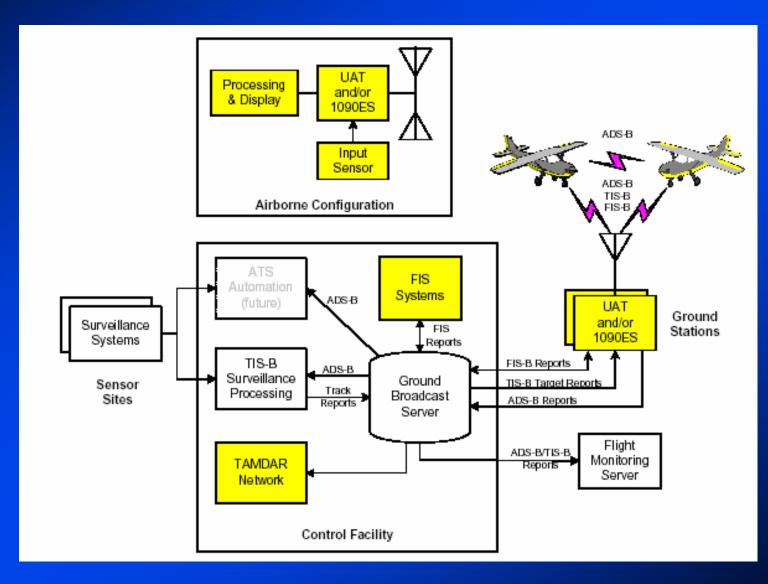# VDL-3 Team Members

General Aviation

UAT

UAT Messages

- Additional Ground-to-Air Textual Products
    - AIRMET
    - SIGMET
    - Convective SIGMET
    - TFR

- Weather Sensor (TAMDAR) data Air-to-Air & Air-to-Ground
    - Type 2 ADS-B message, using unreserved bits with no additional messages transmitted
        - Temperature
        - Wind Direction
        - Turbulence
        - Wind Speed
        - Humidity
        - Airspeed
        - Icing
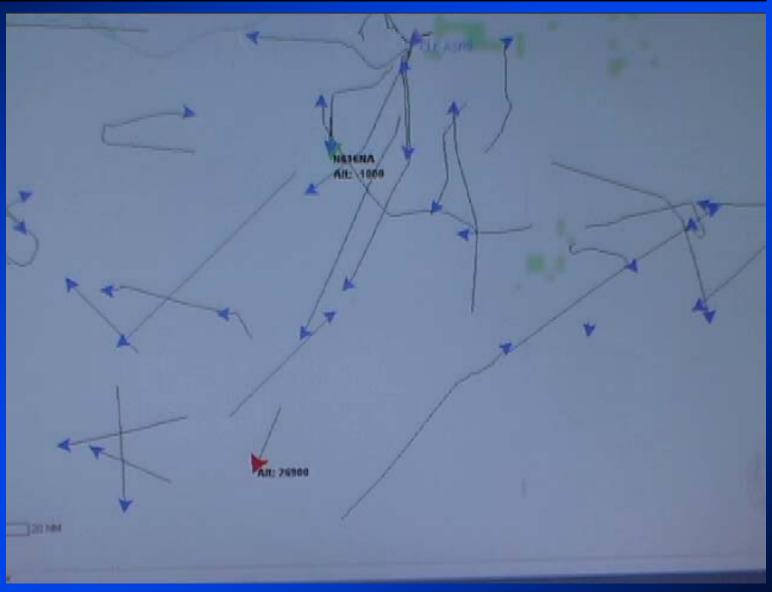
UAT Architecture

UAT Flights

Summary

added objectives.

- All equipment modifications were software based in order to allow the reception and transmission of these additional messages.

- All modifications were made within the accepted standards or in a manner consistent with the standards.

- These changes were worked closely with industry partners with a path toward certification.

Raw Message Display

UAT Airborne Msg Display – Msg Valid

Header
Payload Type	2
Address Qualifier	0
Address	2

State Vector
Latitude	39.44568
Longitude	-74.56374
Altitude Type	1
Altitude	-75
Nav Integrity	9
Air-Ground State	Ground
UTC Coupled	True
Tis-B Site	0

Auxiliary State Vector
Secondary Alt	-1

On Ground
Ground Speed	1
Trk Ang/Head Fmt	0
Trk Ang/Head	0
A/V Len & Width	0
POA	False

TAMDAR Msg Display –
Temperature	7.9
Wind Speed	9
Wind Direction	8
Humidity	7
Icing	1
Normalized Turb	112
AC Constant	22
Data Quality	False